Assessing the RQ AGN population

Results from observations of the G23 field with ASKAP and ATCA

Isabella Prandoni*

[INAF – IRA]

and the EMU RQ AGN WG
in collaboration with GLASS

*CSIRO visitor - June-September 2019

The EMU RQ AGN Team

~ 40 scientists (all around the world)

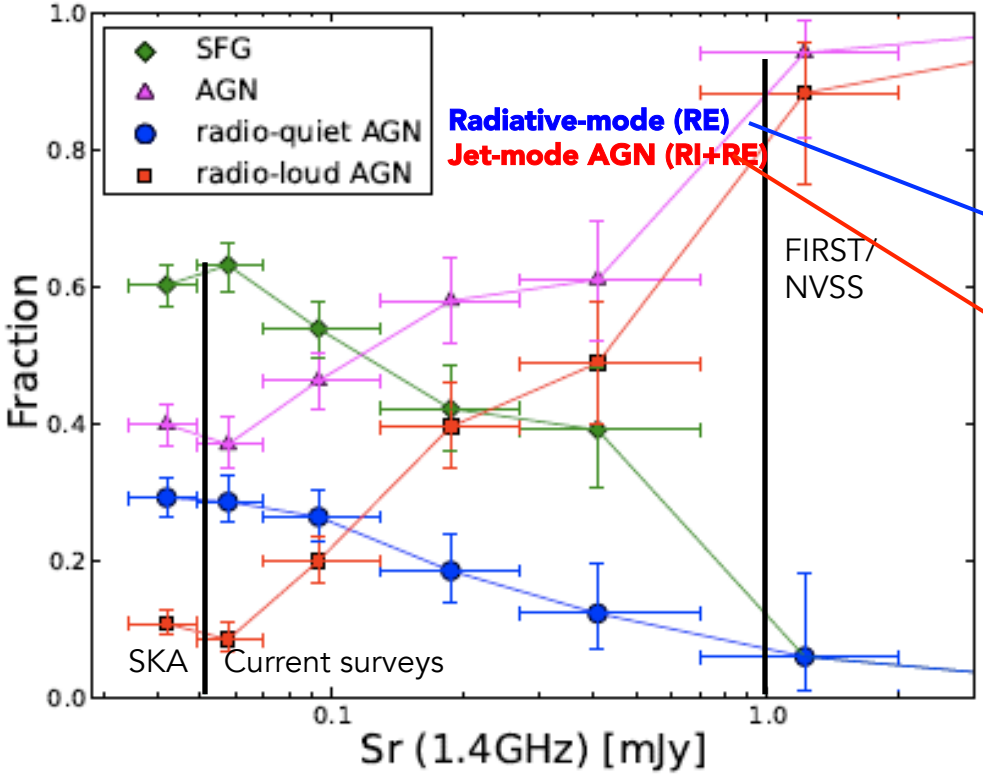
BUT special thanks to:

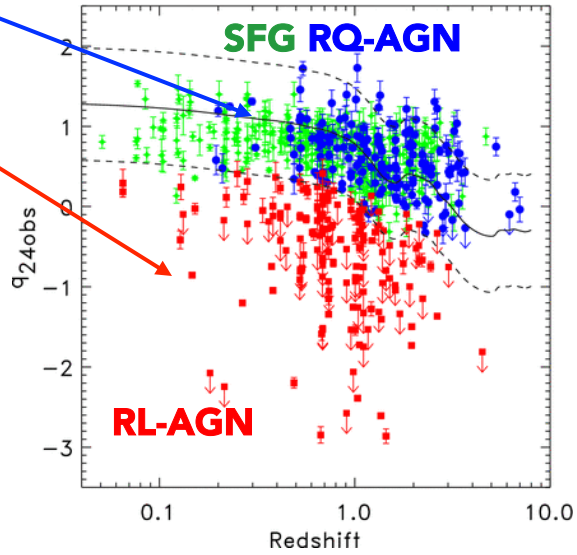
Tom Franzen (ASTRON)
Gulay Gurkan (CSIRO until mid August)
Lucia Marchetti (UCT)

The promise of next-generation RC surveys

- Complete census of SF, AGN activity, up to high-z and down to RQ regime
- Co-evolution of SF AND AGN
- Role of AGN feedback [QSO winds & radio jets]
- not dust extinction/gas obscuration effects

ECDFS S>40 uJy (→ 200 uJy @ 150 MHz)
Adapted from Bonzini+2013





The promise of next-generation RC surveys

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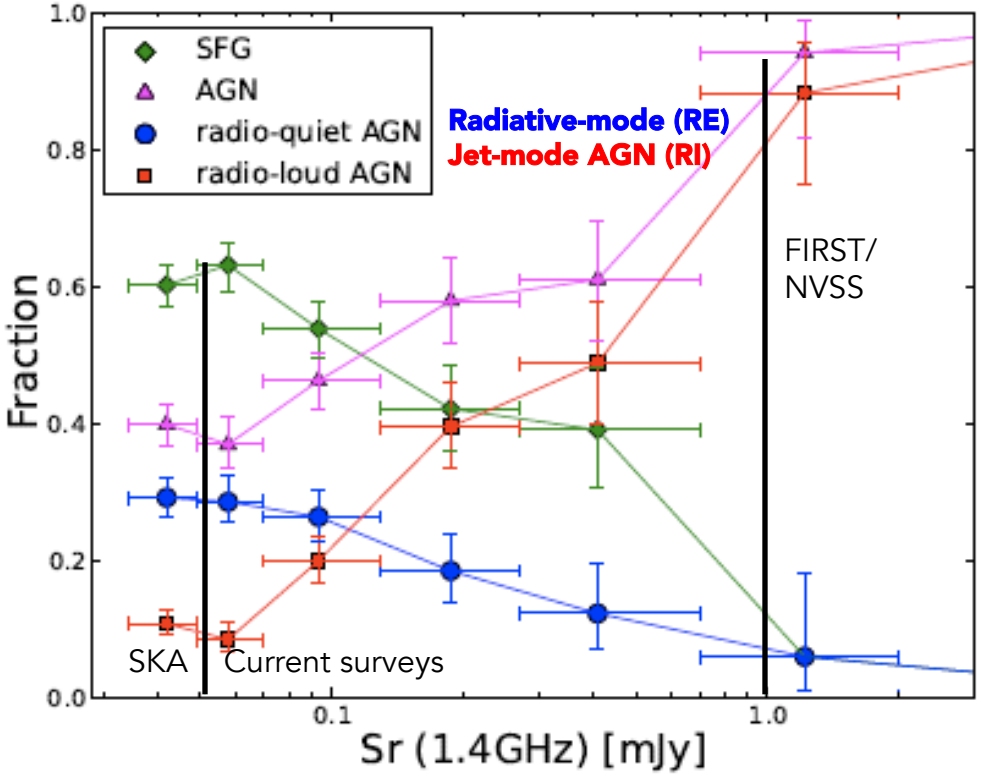
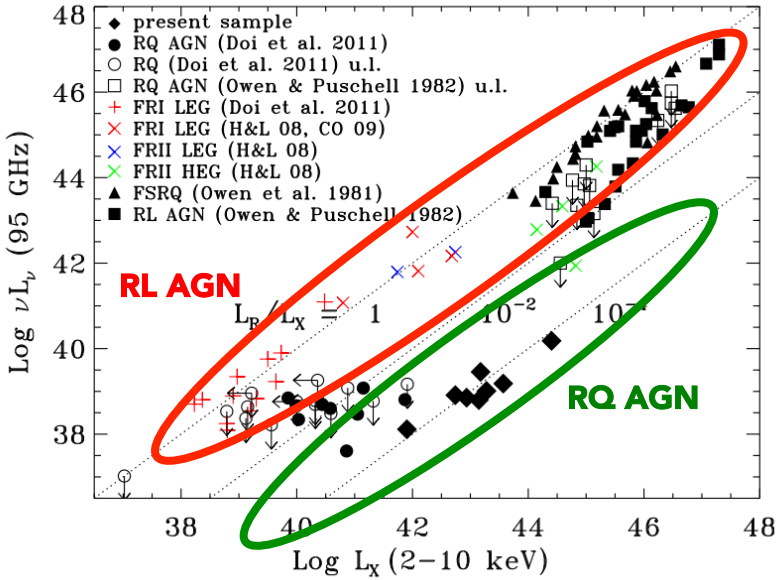


Physics of radio emission

- RQ/RL bimodality;
- Origin of radio emission in RQ AGN
- radio duty cycles/feedback physics

BH fundamental plane

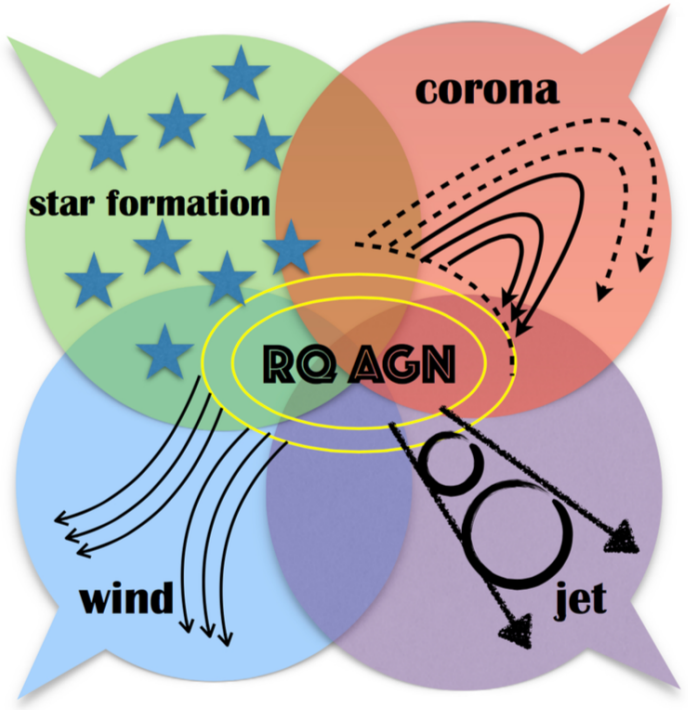
Behar+ 2015



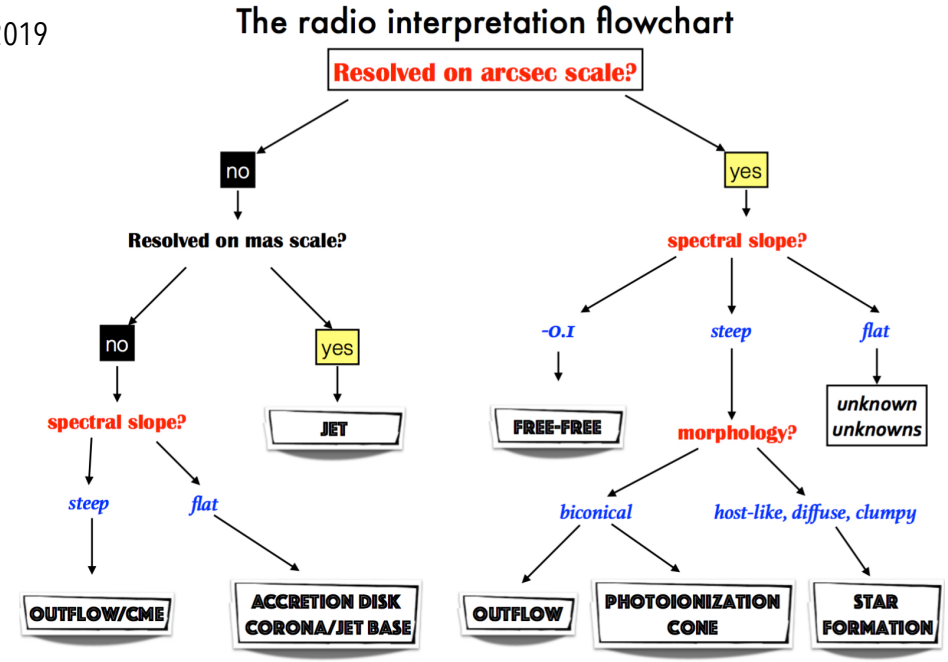
The Origin of Radio Emission in RQ AGN

Evidence of radio excess in ~30% of RQ AGN (DelVecchio+17) [see also VLBI deep field follow-ups]
➔ SF and AGN related emission likely co-exist on a broad range of relative proportions

Which mechanism is responsible for the AGN emission?



Panessa+ 2019

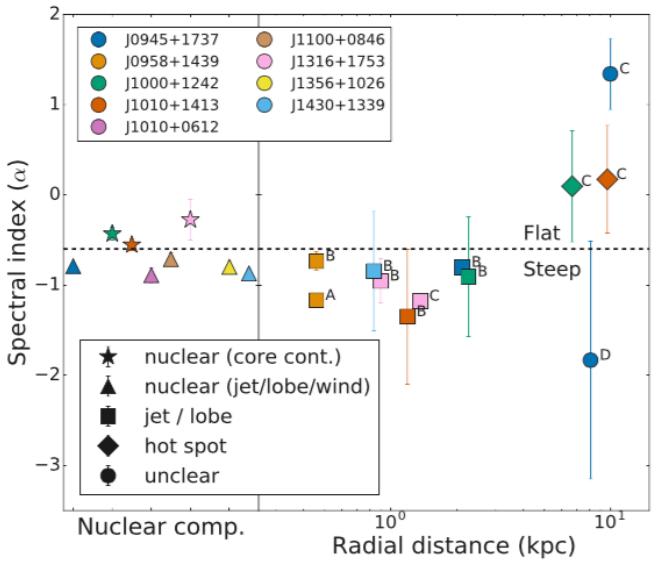


Radio-jets in RQ AGN?

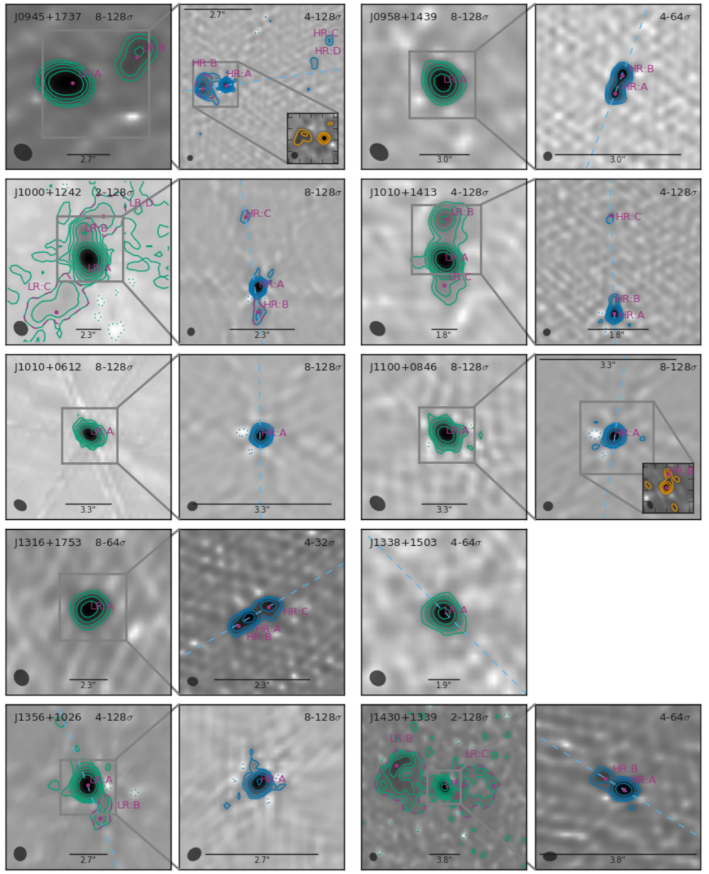
- **sub-galactic radio jets** (on 2-5 arcsec scales, or 1-25 kpc scales) are seen in 8/10 Rex **RQ QSO at z<0.2 (Jarvis+19)**
- radio spectra and sizes consistent with compact radio galaxies

JVLA+eMERLIN 1-7 GHz

10 Type 2 RQ-QSO (Rex) @z<0.2 with OIII outflows



Jarvis et al. 2019



Radio Feedback in RQ AGN?

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- radio spectra and sizes consistent with compact radio galaxies
- **radio jets seem to trace optical outflows**

JVLA+eMERLIN 1-7 GHz

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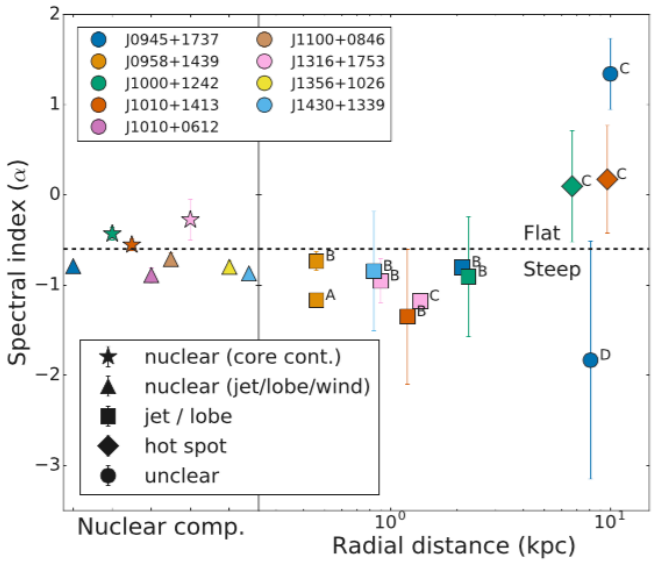
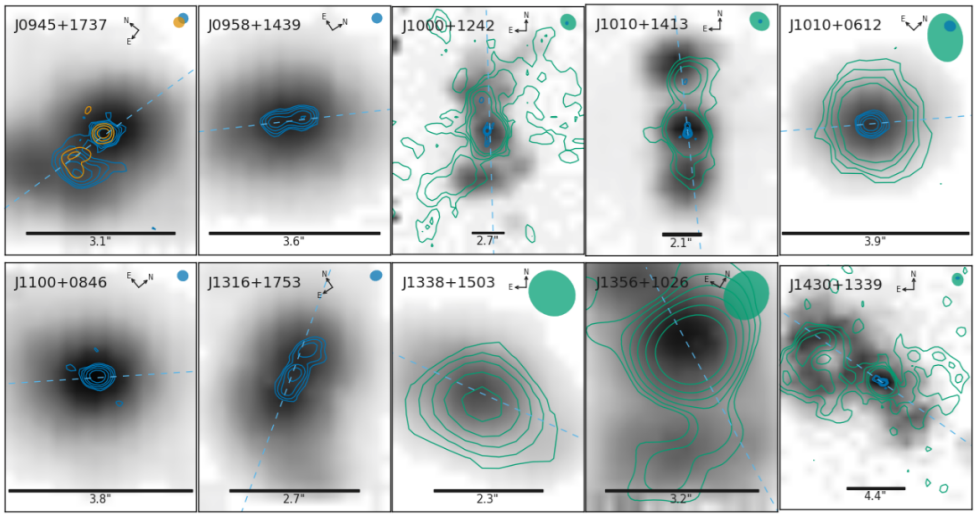
Jarvis et al. 2019





Radio Feedback in RQ AGN?

❖ **Is there any link between radio emission and AGN outflows?**

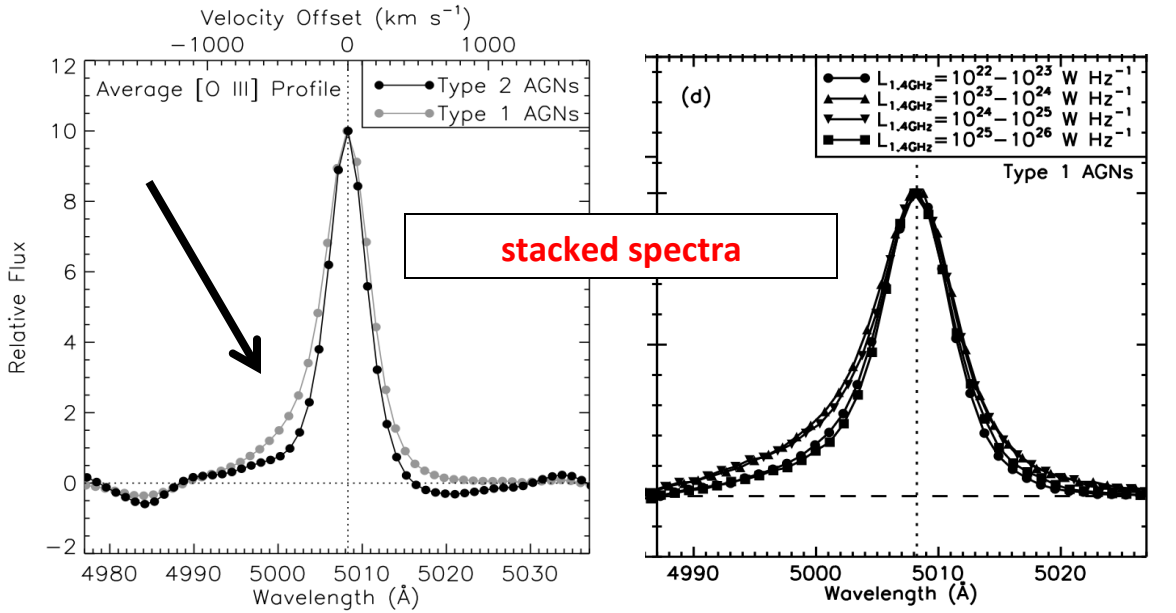
- SDSS-selected AGNs + NVSS for radio counterparts

➢ Stacking of SDSS spectra show significant OIII outflows (500-1000 km/s) in Type 1 and 2 AGN

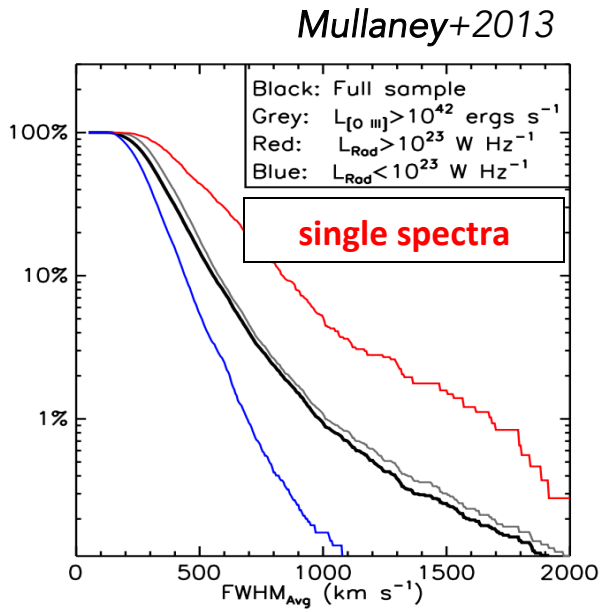
➢ larger outflow velocities seem to be associated to L(1.4 GHz) ~$10^{23\text{-}25}$ W/Hz radio sources

➢ strong correlation between radio luminosity and outflow velocities in SDSS Type 1 & 2 AGN

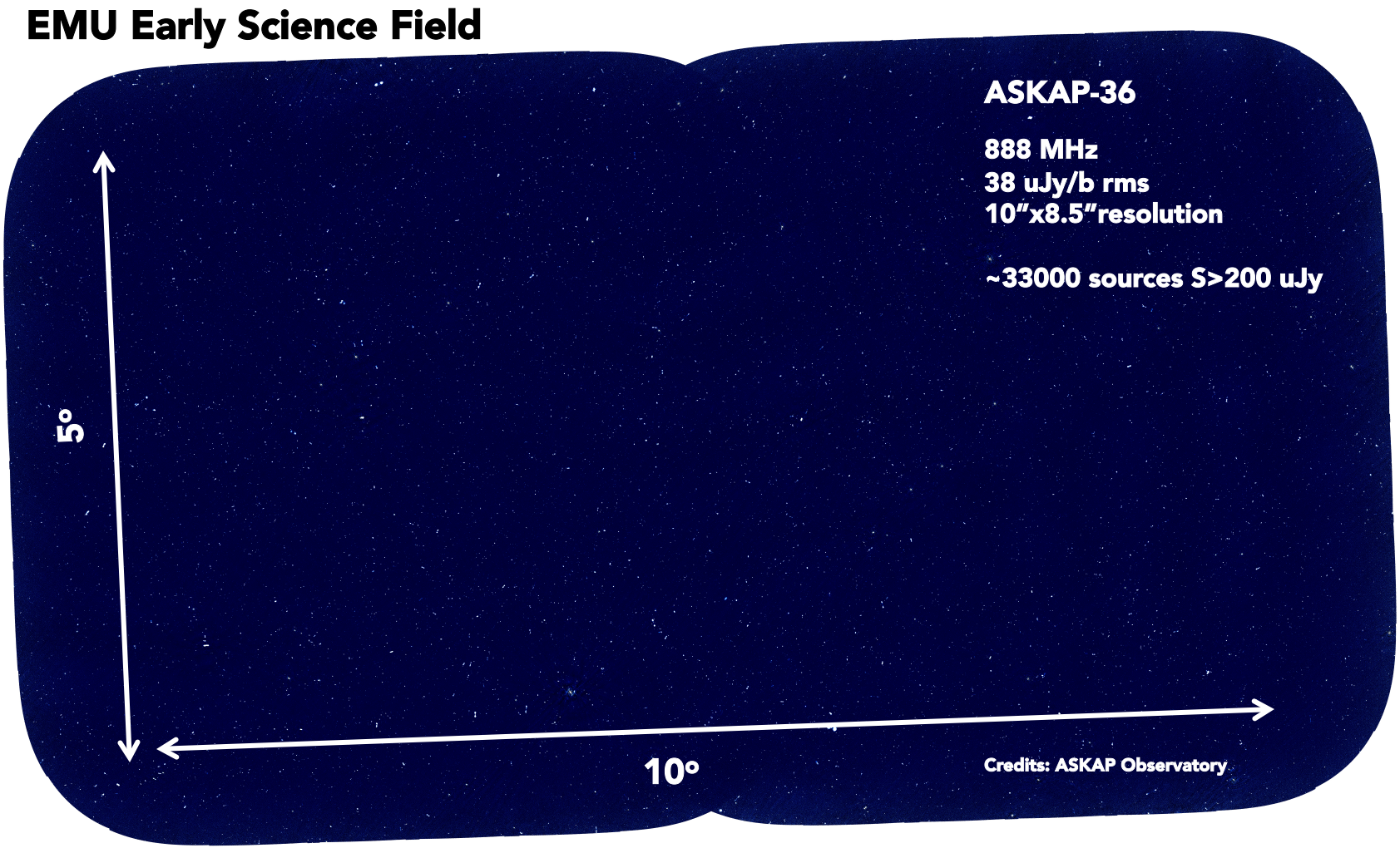
<u>But strongly dominated by NVSS upper limits (>90%)</u>



Mullaney+2013



GAMA G23 Field with ASKAP



GAMA G23 Legacy Value

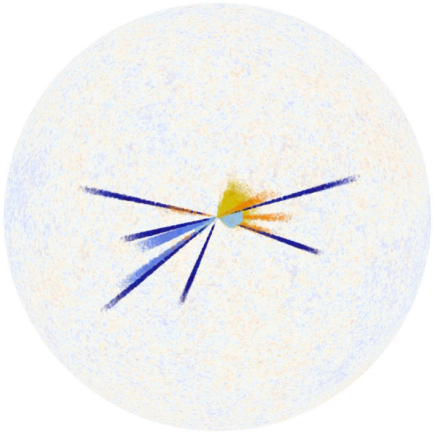
GAMA → ~60,000 optical spectra up to z~0.4

Future WAVES survey plans to target G23:
- fainter magnitudes and GAMA-like completeness to z ~ 0.8
- ~0.5M redshifts/spectra expected in G23

G23 has outstanding multi-wavelength coverage (GALEX,VST,VISTA,Herschel) → photo-zs

Radio coverage from MWA (70-230MHz), SUMSS (845 MHz), NVSS, to EMU

GLASS (PI M Huynh)
- Adding 5.5 and 9.5 GHz data provides 2 decades in radio frequency coverage
- uGMRT Band 3 (~400 MHz) observations ongoing to fill the gap between MWA and EMU



Credit: WAVES Collaboration

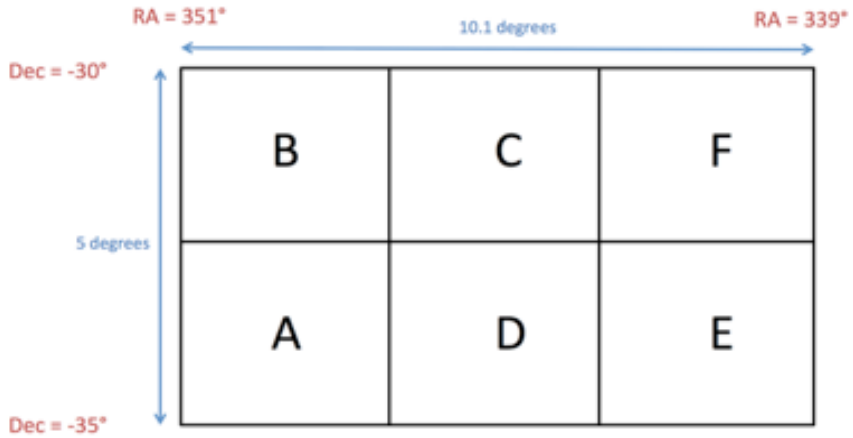
Courtesy M. Huynh

The GAMA Legacy ATCA Southern Survey (GLASS)

A Legacy 4cm Survey of the GAMA G23 Field

In a nutshell:

- Deep and wide 5.5 and 9.5 GHz survey of the GAMA G23 field (centered on RA 23 hours, Dec -32.5 deg)
- Cover 50 sq deg to ~30 microJy rms at 5.5 GHz and ~50 microJy rms at 9.5 GHz
- Understand radio AGN populations and their role in galaxy evolution
- Trace Star Formation with Thermal Radio Emission



Courtesy M. Huynh

GLASS Semester One – Region D

5.5 GHz:

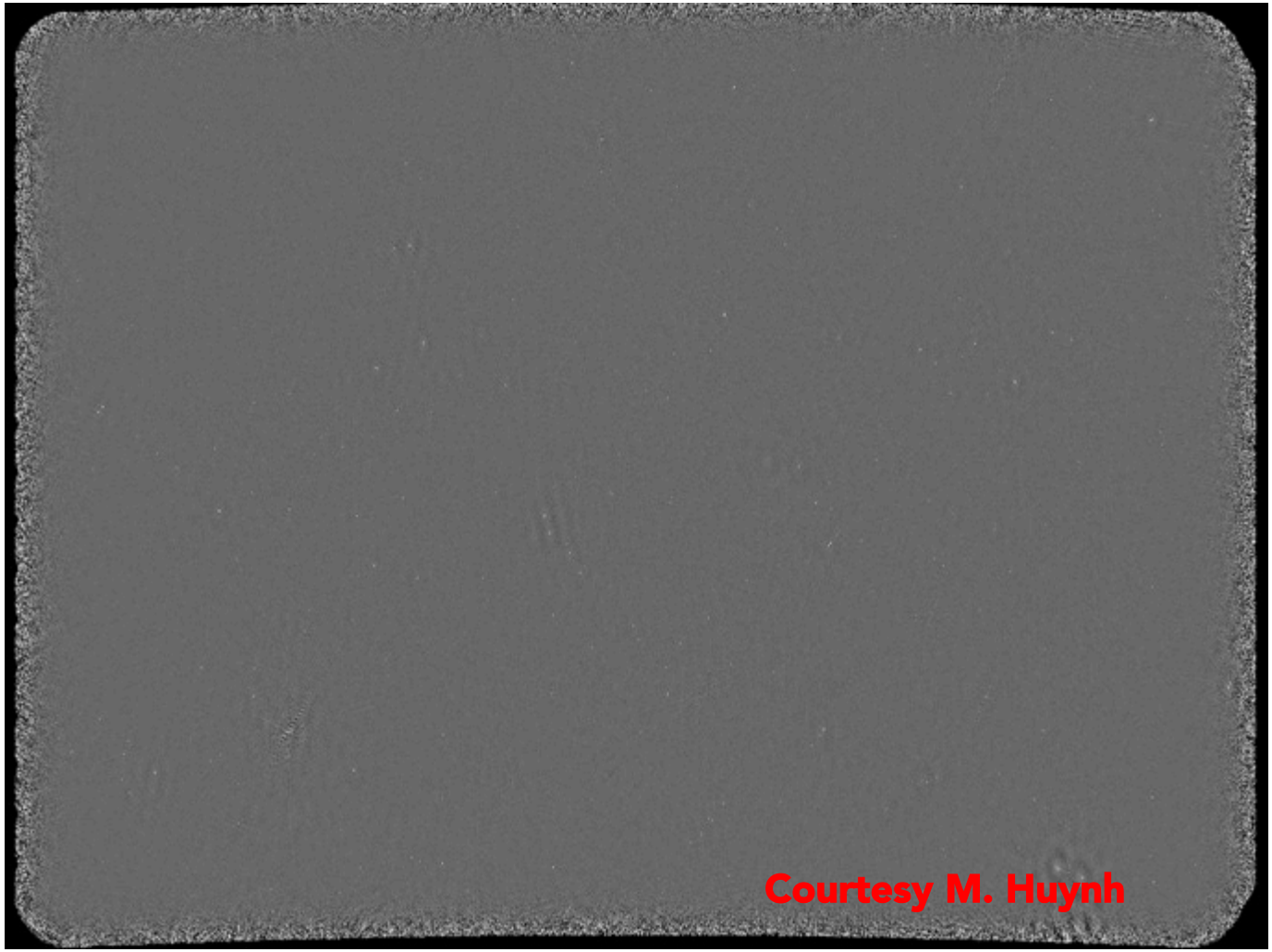
3.4 x 2.5 deg

res. 4″x 2″
~24 uJy/b rms

9.5 GHz:

3.4 x 2.5 deg

res. 3.4″x 1.7″
~40 uJy/b rms



G23 Legacy

Multi-band / multi-frequency data collected and made available to the EMU collaboration:

- PyBDSM ASKAP radio catalogue (under validation; G. Gurkan)
- GAMA- and WISE-selected AGN catalogues (L. Marchetti)
- radio forced photometry (Gurkan)
- GAMA multi-band photometry, Ha-based SFR (S. Driver, L. Davies)
- photo-zs (EAZY), stellar masses & SFR (mu) (N. Taylor)
- HELP data products (M. Vaccari)

- Scientific use subject to publication policies

Projects for G23

Proposed/Ongoing Projects on G23

PI	Title / Description	Data used	Co-I
I.Prandoni	The Radio – Gas kinematics Connection / Explore correlations between radio luminosity and OIII outflows for various RE AGN classes – study spectral index distribution and radio morphology with GLASS	AGN GAMA catalogue / GAMA line equivalent widths/ ASKAP catalogue and forced photometry / GLASS for spectral index and high resolution morphology/ stellar masses and SFRs (not mandatory)	L.Marchetti G.Gurkan
G. Gurkan	Constraining the evolution of the faint radio source population/ Paper presenting the PyBDSF radio catalogue, the derived source counts (total and sub-populations) and sub-population LFs. Comparison with existing evolutionary models (Wilman+08,10; Mancuso+17; Bonaldi+18).	ASKAP catalogue, GAMA+photometric catalogues, incl. photoz/ stellar masses and SFRs (not mandatory)	I.Prandoni P. Padovani D. Leahy
I. Wong	very low-z radio quiet AGN	in collaboration with GLASS data (Jonny Rogers, Minh etc) as well	G.Gurkan, L. Marchetti, I. Prandoni ++
L.Marchetti	Investigate the entire population of WISE (only) or WISE+optical selected AGN exploiting PyBDSF fluxes in the Radio or forced photometry where needed. How do they compare with the one selected in the Optical? is there an evolution with z of their physical properties or a relation with the environment ?	Multiwavelength Optical GAMA photometry + optical spectroscopy + WISE (all-wise & possibly unwise?) + PACS/SPIRE from HELP (or HATLAS ?) + physical quantities (SFR, stellar masses) + photoz (from GAMA or KiDS DR4) + PyBDSF catalogue & forced photometry on WISE position + Possibly using GLASS as well.	I.Prandoni G.Gurkan M.Vaccari D. Leahy P. Padovani
D. Leahy	Comparison of AGN diagnostics: IR with optical (BPT). How do AGN diagnostics compare for the radio quiet galaxies (WISE plus optical spectra)? How do the AGN diagnostics compare for the radio emitting subsample?	Optical GAMA spectral line catalog + WISE+ PyBDSF radio source catalog + GAMA stellar masses; may use forced photometry on GAMA galaxy positions to increase WISE and radio source sample size.	I.Prandoni
Norris & Park	Classifying G23 sources using machine learning techniques	validated PyBDSM radio catalogue/optical photometry	

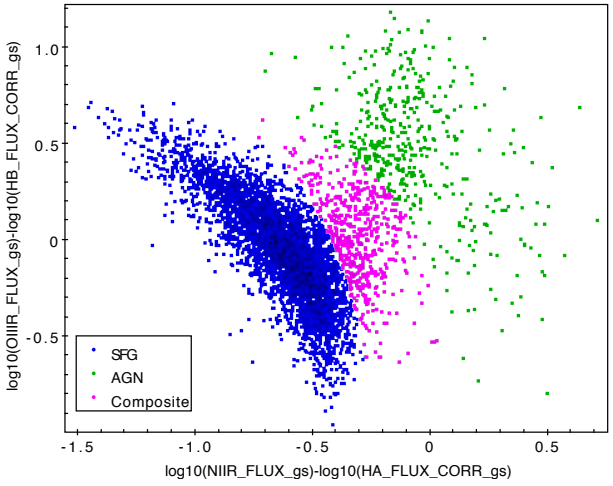
RQ AGN in G23 Field

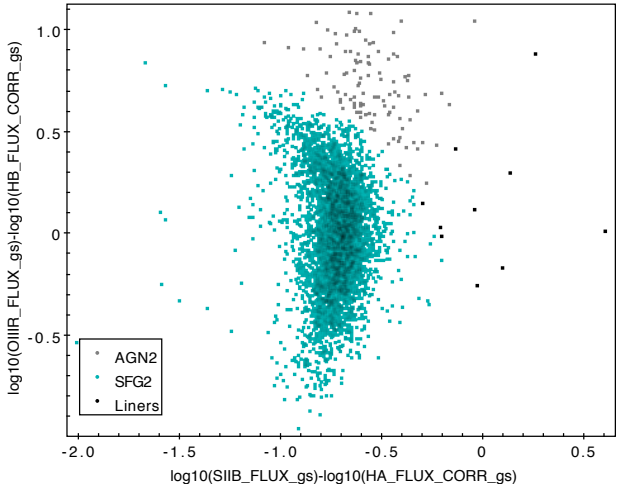
GAMA Selected: **1021 AGN with I<19.2**: 232 Type 1 and 789 Type 2

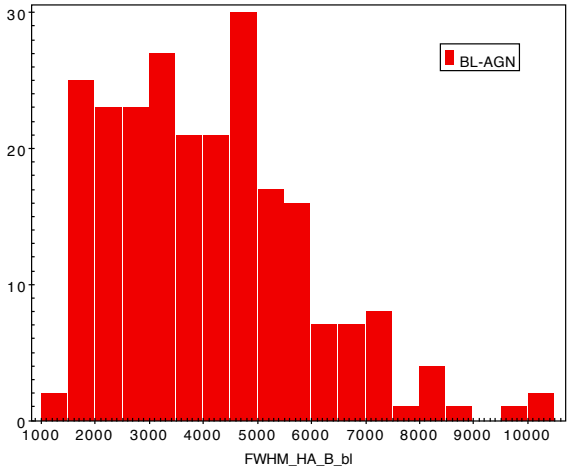
- broad lines (Gordon+2017) + BPT (Kewley+2006)
- Limited to High-quality spectra and all lines SNR>4 ➔ z<0.35

~50% detected in ASKAP-36 cat / ~50% forced photometry: **G. Gurkan**
(cfr. Mullaney+2013: from ~24000 SDSS AGN to ~2000 (<10%) detected in NVSS)

GAMA-selected AGN Catalogue: **L. Marchetti**





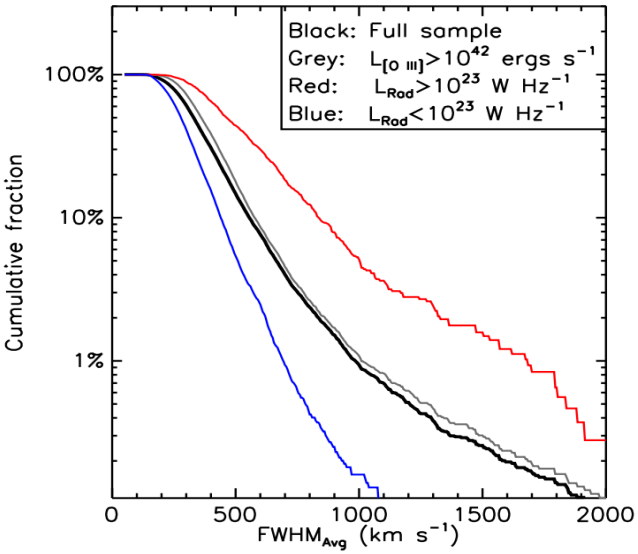


Radio Feedback in RQ AGN?

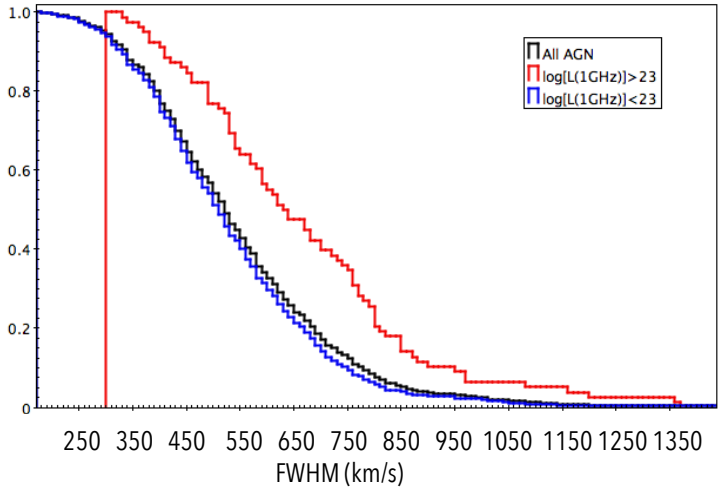
❖ **Is there any link between radio emission and AGN outflows?**

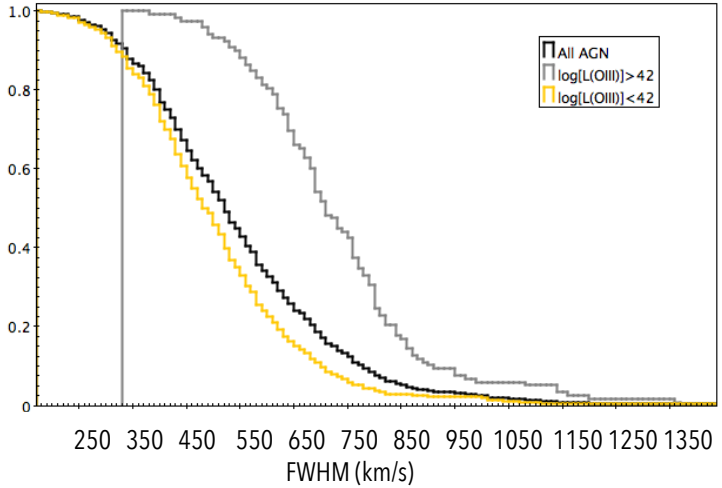
- strong correlation between radio luminosity and outflow velocities also found in G23
- driven by know correlation between L(OIII) and L(1.4 GHz)?

Mullaney+2013: SDSS + NVSS



Prandoni+in prep.: GAMA + ASKAP-G23





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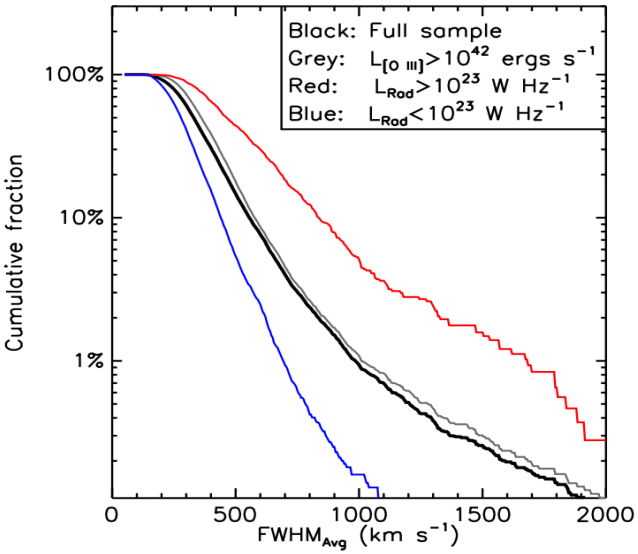
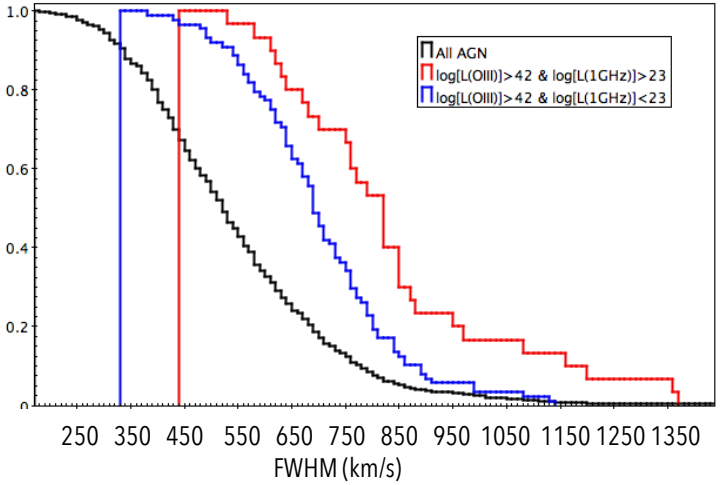
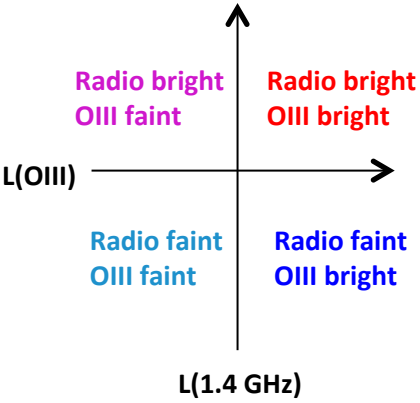
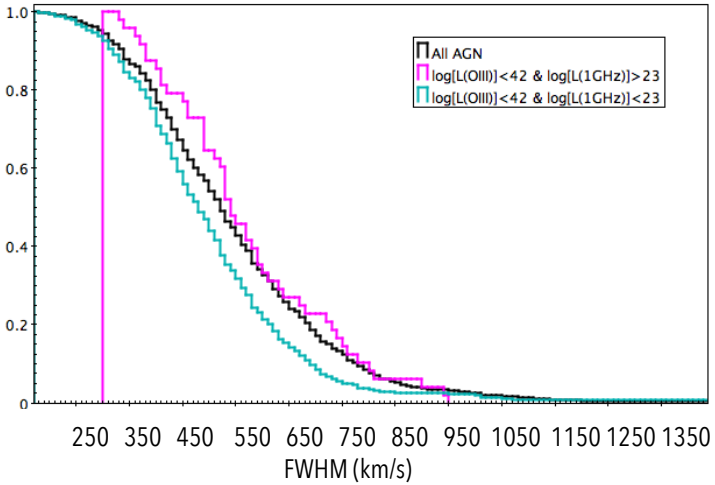
- driven by know correlation between L(OIII) and L(1.4 GHz)?
- **radio correlation dominant**

Mullaney+2013: SDSS + NVSS









Prandoni+in prep.: GAMA + ASKAP-G23

Radio Feedback in RQ AGN?

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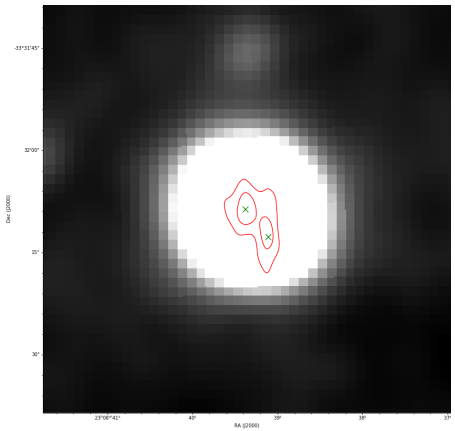
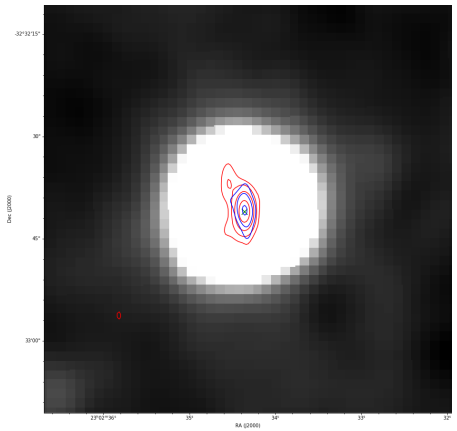
- **radio correlation dominates in QSO**
- sub-galactic radio jets (1-25 kpc) in 10 **Rex RQ QSO at z<0.2** are seen to trace optical outflows (Jarvis+19)

GLASS 5.5 & 9.5 survey (PI M. Huynh): 24 uJy/b rms @ 5.5 GHz; 40 uJy/b rms @ 9.5 GHz

- spectral index in progress**;**
- **GLASS resolution (~4"x2") is sufficient to resolve our local GAMA AGN sample?**
  - ➢ 54 OIII and Radio bright sources:
    - ◆ 11 show jets at ASKAP resolution
    - ◆ other 16 are located in GLASS Regions A & D and 13 detected
    - ◆ 2 show clear jets (7-30 kpc) at 5.5 GHz; other 3 some signs





spectro-morphological classification
... work in progress ...

Prandoni+in prep.: GAMA + ASKAP + GLASS

Summary

Promise of Next Generation RC surveys:

- Co-evolution of SF and AGN across cosmic time [no obscuration/extinction effects]
- Aspects where radio band information is essential
  - Origin of radio emission in RQ AGN
  - RQ/RL dichotomy; radio duty cycles

Current understanding of RQ AGN:

- ~30% dominated by AGN radio emission (COSMOS; Smolcic+2017))
- recent modeling of RQ AGN assuming in situ co-evolution scenarios (SB + QSO/AGN phases) can explain observations (Mancuso+2017; Prandoni 2018)
- high resolution (0.2"-0.5") imaging of RQ AGN - first results:
  - z<0.2 (Jarvis+19): radio-jets (1-25 kpc) in Type 2 RQ QSO
  - z~0.5-1.5 (Guidetti+17; Prandoni+ in prep.): 2 components:
    a. no Rex: steep and 5-10 kpc consistent with SF origin
    b. Rex: steep and 1-5 kpc consistent with jets; a fraction → VLBI core (10-100 pc)
- Strong correlation between radio luminosity and OIII outflows: SDSS (Mullaney+13); G23 (Prandoni+ in prep.)
  - radio jets found to trace outflows in 10 Type-2 (Rex) RQ-QSO (Jarvis+19)

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Ongoing surveys are revolutionizing our knowledge of radio source populations
..... more expected in the next future .....

Thanks